PRECISION FLOW-CONTROL DEVICE USING MULTIPLE SHUTTERS

Cross Reference to Related Applications

[0001] This application claims priority under 35 U.S.C. § 119 to European Patent Application No. 02447266.4, filed on December 20, 2002.

Field of the invention

[0002] The present invention relates to a class of devices such as control valves, intended for the proportional control of flow.

[0003] The term "flow" relates both to a material fluid, as for instance in the case of a valve controlling a liquid or gaseous flow, and to an electromagnetic radiation, as for instance in the case of a shutter or diaphragm for visible light.

[0004] Examples of application areas are thus the area of precision control valves in aeronautics, optics or the multimedia (cinema, photography, etc.).

State of the art

[0005] Proportional control valves having a motor or an actuator running a single shutter of the plug, butterfly or grid type, etc. are known.

[0006] The resulting absolute precision in the shutting directly arises from the combination of:

- the "precision" defined by the reproducibility of a motion, the resolution or the smallest achievable motion, the hysteresis or mechanical clearance in the system, etc. of the actuator or motor element of the device described and
- the precision relative to the characteristic of the shutter used: the linearity or evolution in the resistive feature, such as the drop in pressure for a valve, the percentage of shutting for a diaphragm, etc., of the shutter as a function of its shift, the reproducibility of this resistive feature, the mechanical clearance in the transmission, etc.

[0007] It thus can be noted that in the case of existing proportional valves, a requirement for very high shutting precision entails the need for very high precision in the production of the critical components of such valves, which proves to be expensive.

Aims of the invention

[0008] The present invention aims to provide a solution allowing to avoid the drawbacks of the state of the art.

[0009] In particular, the invention aims to provide a very-high-precision flow-control device at a reasonable cost and in particular not requiring the production of very-high-precision parts.

Main characteristic elements of the invention

[0010] The present invention relates to a shutter device for the precision control of a flow, comprising at least one organ for shutting one section for the passage of the flow, the motion of which is proportional to that of an actuator controlling it, wherein said device comprises at least two shutter organs controlled by the actuator by means of a transmission allowing to obtain slightly different proportionality coefficients for the motion of said organs.

[0011] According to a first preferred embodiment of the invention, said shutter organs both have a rotary motion controlled by a motor shaft that is actuated by hand, electrically or otherwise, by means of a transmission allowing to transmit to them the motion of said shaft with slightly different transmission ratios, preferably reduction ratios.

[0012] Advantageously, said rotary shutter organs are in the form of plugs, butterflies or grids that may move independently of each other.

[0013] Preferably, said transmission is a transmission by gear, by roller or by chain.

[0014] Advantageously, the device of the invention comprises a grid shutter where said shutter organs have a passage section or aperture in the form of a crown section with the same axis, internal and external radii, the aperture being limited to an angle α less than or equal to 2π, preferably less than or equal to π.

[0015] According to another preferred embodiment of the invention, said shutter organs both have a linear motion and are preferably curtain shutters.

[0016] The motor shaft may be provided with two interdependent pinions, in the case of two rotary or linear shutters. The motor shaft may also be provided with a double rack, in the case of two rotary shutters activated by a linear motion.

[0017] Another aspect of the invention is the use of a shutter device such as described above in a high-precision control valve, for instance in the aeronautical and space sectors.

[0018] Yet another aspect of the invention is the use of a shutter device such as described above as a precision shutter for electromagnetic radiation, preferably for visible light, such as the diaphragm of a projector or of a radiation sensor.

Short description of the figures

[0019] Figure 1 shows an example of a simple shutter with a passage section in the form of a partial crown, with one or several perforations, according to the state of the art.

[0020] Figure 2 shows a shutter with two organs, each one presenting a passage section in the form of a partial crown according to the present invention.

[0021] Figure 3 diagrammatically shows the shutter with two organs of Fig.2 where said organs are actuated by gear transmission.

Description Of A Preferred Embodiment Of The Invention

[0022] The present invention will be described hereinafter with reference to a specific case of the state of the art shown in Fig.1 and consisting of a simple rotary shutter 1 with a passage section 3 that is a crown section of axis 2 and aperture α (e.g. $\alpha = \pi$).

[0023] The device proposed by the present invention comprises:

1. a mechanical actuator;
2. a shutter with two organs, O1 and O2, which move:
   - proportionally to the motion of the actuator;
   - with slightly different proportionality coefficients;
3. a mechanical transmission allowing the precise transmission of the actuator motion with slightly different reduction ratios.

[0024] The operating principles may be detailed by the following example which relates, as mentioned above, to rotary shutters with a passage section in the form of a partial crown with a given angle α.

[0025] Being:

- $\delta\theta_m$, an incremental shift of the rotary shutter,

- i_1, the transmission ratio between the actuator shaft and the shutter O1 (see Fig. 2),
- i_2, the transmission ratio between the actuator shaft and the shutter O2,
- $\varepsilon = i_2 - i_1$ ($\varepsilon << 1$),
- $\delta\theta_1 = i_1.\delta\theta_m$, the incremental shift of the shutter O1, resulting from an actuator motion $\delta\theta_m$,
- $\delta\theta_2 = i_2.\delta\theta_m$, the incremental shift of the shutter O2, resulting from an actuator motion $\delta\theta_m$,
- S1, pass surface of shutter O1,
- S2, pass surface of shutter O2,
- the form of the shutters being for instance a crown section of aperture α (radians), internal radius r_{int} and external radius r_{ext} identical for both shutters,

$$S1 = S2 = S = \alpha.(r_{ext}^2 - r_{int}^2)/2 \ (0 < \alpha \leq 2\pi),$$

- a valve comprising the above-described elements with the initial conditions:

$$\theta_m = \theta_1 = \theta_2 = 0.$$

[0026] Hence:

- for an incremental shift $\delta\theta_m$ of the actuator shaft, the resulting motion of the shutters equals

$$\delta\theta = i_2.\delta\theta_m - i_1.\delta\theta_m = \varepsilon \, . \, \delta\theta_m \, ;$$

- the evolution in the effective passage section becomes:

$$\delta S = \delta\theta.(r_{ext}^2 - r_{int}^2)/2 = \varepsilon.[\delta\theta_m.(r_{ext}2 - r_{int}2)/2] = \varepsilon \, . \, \delta\theta_m \, .S/\alpha;$$

[0027] This relationship shows that if ε is small, a relatively large motion by the motor shaft leads to a small evolution in the pass section S. For instance, if $\alpha = \pi$ and $\varepsilon = 0.01$, then a motion of the motor shaft of amplitude π (half a turn) causes an evolution of $0.01.\pi S/\pi$, i.e. equal to 1 % of the pass section;

- the shutter O1 completes a turn after i ($= i_1$) turns of the motor shaft;
- the shutter O2 completes a turn after $(i+\varepsilon)$ turns of the motor shaft;
- both shutters O1 and O2 will be back in their respective start position after a number of turns equal to

$$i*(i+\varepsilon),$$

i.e. of the order of i^2.

[0028] In concrete terms, the device in the present invention may take the form of various preferred embodiments depending for instance on whether the motion of the shutter is rotary or linear.

Rotary motion

[0029] The differential motion may be achieved by classical, mechanical drive means such as for instance:

- gears with slightly different transmission ratios; these gears may be of any type known to those skilled in the art such as, for example, cylindrical pinions with straight or helical teeth, a toothed crown and a worm screw, hypoid pinions, etc.;
- roller transmission;
- chain transmission.

[0030] Figure 3 is a diagrammatic illustration of a rotary shutter in a valve 5 where the differential motion of the two elements O1, O2 forming it is achieved by means of a gear transmission 4 between the motor (actuator) 6 and the shutter 1.

Linear motion

[0031] The same principle may be applied to linear (curtain) shutters.

[0032] The device according to the invention has the advantage of offering a very-high precision of the control system in an open loop without requiring great precision in the individual parts.